tration of a pipe was used with the endeavour to aid the conceptions in some respects, rather than for rigid accuracy of comparison. The idea of the exterior fluid being *at rest* was subsequently guarded against by stating that it had "important functions" to perform. In regard to the fact of only mentioning "friction" as an element of resistance in a totally immersed body, I wished rather to convey the general idea that if no *energy* were given to the molecules of the surrounding liquid at the passage of the immersed body, there would be no "resistance." The object of the article was, however, not so much to lay stress on these points as to notice certain, perhaps less appreciated (*à priori*), aspects of the problem.

S. TOLVER PRESTON

Songs of Birds

YOUR correspondent "A. N." (*antea*, p. 97) does not seem to be aware that the best observers are nowadays agreed in believing that the hen cuckoo does not sing. Hence his suggestion in regard to the difference of note observed by Mr. Birmingham (*antea*, p. 76) hardly applies to the case in question.

ALFRED NEWTON

Magdalene College, Cambridge, June 6

I HAVE been in the habit of observing the notes of cuckoos, and have noticed that the musical interval is very variable. It is not always, or even often, amenable to our tempered scale, but may lie anywhere between a major 2nd and a 4th. The major 3rd seems to be about as frequent as the minor. The interval may vary in the same bird, as it is well known that the cuckoo's song alters greatly with the approach of summer.

FRANK J. ALLEN

St. John's College, Cambridge, June 6

Cup-marked Stones

ON a large block of fine-grained hard whitish sandstone near Burghead, Elgin, are forty-four cup-marks of various sizes, but all very finely formed. Four of the cups have channels or grooves of various lengths and running in different directions, but none to the edge of the stone. Five have one ring, and channels of various lengths, and in different directions. Four have got two rings and channels, and one has three rings and a channel. In some cases the rings are not complete, that is, they stop short on either side of the channel, but close to it. One cup has a simple ring.

From this example, and if I recollect the figures in Sir J. Y. Simpson's work, there seems to be but few cases in which the channels run to the edge of the stone.

Out of a considerable number of cup-marked stones partly on finely ice-polished rock surfaces and partly on detached blocks large and small, in Elginshire, this is the only one that has rings and grooves. A full description of these, with plans, I have nearly ready to lay before the Society of Antiquaries at one of their early meetings of next session. JAMES LINN

Keith, June 2

THE DUMAS NUMBER.—In reply to numerous inquiries we may state that the portrait of M. Dumas should form the frontispiece to vol. xxi., and the article by Dr. Hofmann be placed after the index in the beginning of the volume.

ENERGY AND FORCE[1]

[ON March 28, 1873, Clifford delivered a Friday evening discourse on this subject at the Royal Institution. By some accident no trace of it, not even the date or title, appears in the printed *Proceedings*. Thus the lecture escaped notice when Clifford's literary and scientific remains were collected in the summer of last year. A few weeks ago I lighted on my own rough notes of it taken down at the time, probably the only record now in existence. These I have written out, with only so much alteration and addition (indicated by square brackets) as necessary to make them intelligible. The paper thus produced has been seen by Clifford's friend and mine, Mr. J. F. Moulton, who (besides his general competence in mathematical physics) was thoroughly acquainted with Clifford's mathematical work and ideas. Mr. Moulton has added, by way of introduction, some remarks founded on this intimate knowledge, which will explain the aims of the discourse and supplement the too meagre report which is all that I am able to reconstruct from my notes.—F. POLLOCK.]

This lecture was, I think, written as a protest against certain loose ideas that had become prevalent relating to energy, motion, and force. The discoveries as to the equivalence of the many forms of energy and the invariability of the total of energy in any system not operated on by external forces (one case of which is the whole material universe), had led philosophical writers and others to treat force as an entity with a separate existence like matter, and also, like it, indestructible. The error of thus treating force as an entity with a separate existence was not an unnatural one in those who had not much acquaintance with the theories of physics. No idea is more consonant with the ordinary modes of thought than that force is a something operating from without on a body, and producing effects thereupon in the shape of an alteration of its motion, so that the quasi-personification of force contained in the above does not appear to be in any way an unwarranted conception. The further step, which ascribes to force an indestructibility as absolute as that of matter, is due to a confusion in the terms used by mathematicians themselves in speaking of these subjects, for which they are to blame. Before the conservation of energy was fully formulated, mathematicians were acquainted with a particular case of the general principle, and it had received the name of conservation of force. This unfortunate appellation, with all its misleading tendencies, was often applied to the general principle when the latter first became known, and hence unscientific writers naturally assumed that force and energy were convertible terms and that they were alike indestructible. These erroneous conceptions had attracted Prof. Clifford's attention, and with his usual zeal for preserving scientific ideas from all taint, he set about correcting them. His mode of doing so is highly characteristic. He strikes straight at the root of the matter, and would have us at once cease to think of force as an entity at all. Indeed he goes so far as almost to warn us against tolerating the conception of a cause as distinguished from its effects.

All we know as to force and motion, he says, is that a certain arrangement of surrounding bodies produces a certain alteration in the motion of a body. It has been usual to say that this arrangement of surrounding bodies produces a certain force, and that it is the action of this force that produces the alteration of the motion. Why have this intermediate term at all? Why should we not go at once from the surrounding circumstances to the alteration of motion which follows? The intermediate term is only a mental inference either from the existence of the surrounding circumstances or from the occurrence of the alteration in the motion; and if we only accustom ourselves to pass from one to the other without its assistance, it will cease to be necessary, and like other useless mental conceptions, be gradually forgotten. And with it will pass all tendency to give to this useless mental phantom any such real and material qualities as indestructibility.

I was not present when the lecture was given, nor do I know otherwise than from these notes how Prof. Clifford carried out these ideas. But in conversation he had often discussed the matter with me, and made me fully acquainted with his views on the subject, so that I am able thus far to confirm the accuracy and completeness of these notes. It will be seen that he defines force as

[1] An unpublished discourse by the late Prof. Clifford. With an introductory note by J. F. Moulton.

"the change of momentum of a body considered as depending upon its position relative to other bodies," thus bringing into direct connection the surrounding bodies and the consequent alteration of motion and rendering the conception of force a superfluous one. In his concluding remarks as to whether we are directly conscious of force, there is the same tendency. He is well aware that such an attempt as his will be viewed with very little favour by the not unimportant school of philosophers who conceive that force is the only thing that we are directly conscious of, and thus he takes the opportunity to combat this idea.

The part of the lecture that refers to energy needs no special remark. He shows, in his usual clear style, at once how much and how little is contained in the law of the conservation of energy. So far from containing in itself the solution of all the changes in the universe, it tells us only one of the conditions that these must obey, and gives us very little information, if any, as to the particular results that follow from the causes that are at work. It is invaluable as a negative law. It enables us to reject with absolute certainty countless hypotheses that would otherwise be temptingly appropriate to elucidate the complexities of nature. But further than that it cannot go. It cannot distinguish between the innumerable hypotheses that satisfy it, of which, after all, only one can be true. J. F. M.

No mathematician can give any meaning to the language about matter, force, inertia, used in current text-books of mechanics.

The old definition of *force* contains the word cause. In the older writers this is a mere manner of speaking; thus Maclaurin defines velocity as the cause of a body changing its position. We now define it as the rate of change of position.

Causation is defined by some modern philosophers as unconditional uniformity of succession, *e.g.*, existence of fire follows from putting a lighted match to the fuel.

This idea must be got rid of to understand force. All universally true laws of nature are laws of co-existence, not succession. Thus, I want to move a thing and I push it, and motion follows. This suggests at first sight the conception of cause and effect being related in succession. But really you change the rate of motion of a thing *at the time* when you push it, not afterwards. So if you drop a thing from your hand, the letting go and the falling down are really simultaneous. Again, the change of motion of a terrestrial body is at every instant dependent on its distance from the earth's centre (though in practice this is neglected for small distances). In every case the law at work is seen to be a law of co-existence, not succession.

Momentum may be roughly described as quantity of motion. A body moving at a speed of say twenty miles an hour, has a certain quantity of motion. If the same body goes forty miles an hour there is twice as much motion; or if twice as much matter goes twenty miles an hour, there is also twice as much motion. Momentum is measured by the quantity of matter moving at a given rate (mass × velocity).

How is the quantity of matter measured if we compare bodies of different substances, such as wood and lead? Not by size: there is another scale by which the quantity of matter in a given body, without regard to the kind of matter, can be measured. [The existence of such a scale and the possibility of applying it are involved in the idea of *mass*.] The simplest method of applying that scale in practice is to weigh the two bodies to be compared at the same place.

Force cannot be explained without stating a law of nature concerning momentum, viz.:—

Suppose a body with a certain momentum to be the only body in the universe; it will go on with the same momentum.

If there is any change, there is another body, and the change depends on the position of that body.

The case of bodies in contact is no exception to this law, but only a particular case. Here the change of motion is called *pressure*. The case of bodies not in contact is illustrated by the motion of the earth about the sun [under the force of gravitation, as we call it].

In all cases change of motion is connected by invariable laws with the position of surrounding bodies. Force, then, has a definite direction [at every instant] at any point in space, and depends on the position of surrounding bodies, and may be described as the change of momentum of a body considered as depending upon its position relative to other things. It embodies the quality of direction as well as magnitude. In other words, it is a *quantity having direction*.

Force, defined as above, is not conserved at all. It may appear and disappear; it is continually being created and destroyed. "Conservation of force" is, mathematically speaking, a contradiction in terms.

Energy [is of two kinds: 1. Energy of motion; 2. Energy of position].

1. In a moving body we have a certain *quantity of motion* [as explained above under the head of momentum]. Thus in a moving railway train let the unit of motion be one carriage going at the rate of one mile per hour; then ten carriages going at the rate of twenty miles per hour have 200 units of motion. [The quantity of motion or momentum in a body may be regarded as travelling with the body, and] energy of motion is the *rate at which momentum is carried along*. [It depends on momentum and velocity jointly, and the energy of motion of a given body] is known when the velocity is known. In practice it is convenient to call the actual amount of energy of motion half this rate. It is expressed by $\frac{1}{2} m v^2$ [*i.e.*, $m v \times v$, not $m \times v^2$: Clifford, in conversation].

2. Energy of position is quite a different thing. If I take a book lying on the table and lift it up, and put it on the desk above the table, it acquires energy of position, and the energy acquired is measured by the weight [assuming gravity to be constant] of the book multiplied by the difference of height between the two positions. [Energy of position, like force, may be said to exist at any point of space, whether a body is there or not.] The difference of energy between two positions is the quantity of work that must be done to remove a body of unit mass from one position to the other.

When a body is let fall from a higher position to a lower one, it has, at the instant when it is let go, no energy of motion; but it gains, in falling, as much energy of motion as it loses energy of position. It is found that the *sum of energy of motion and energy of position is always constant*.

Force, we have seen, is a quantity which has direction. Energy is a quantity which can be greater or less, but has no direction. The name Energy is applied to two different quantities, of which we find the sum to be constant. This constancy is expressed by including them in the common name of Energy, and saying that energy is conserved, or is indestructible. This form of speech might be applied to other cases of alternate immortality, where one of two things comes into existence on the disappearance of the other.

Does the law of persistence of energy mean no more than this? Yes, [it means more when it is used to include the "correlation of physical forces]". Other qualities of bodies are connected with simple energy of motion and energy of position. Such is heat, which we find by experiment can be turned into work. Finding it convertible with energy, we call it a form of energy.

Here we have [it seems] three different things included: energy of motion, energy of position, heat. But as to

heat, it is further established by experiment that in this case the energy of motion does really persist as such. Thus a gas consists of molecules flying about with great velocity, rotating and vibrating, and so having energy of motion. All this energy of motion is what we call heat, and thus heat is a repetition of a known meaning of energy. Again, heat exists between a radiating body and the thing it warms; now the intermediate space is filled by the luminiferous ether, which, being elastic, has in its ultimate parts both energy of motion and energy of position. In these forms the heat exists in the space in question.

In the cases of heat and electricity the form of the persisting energy is pretty well ascertained. But there are cases in which we do not know if it is energy of motion or energy of position, such as that of *chemical energy*. In the burning of coal there is a falling together of carbon and oxygen [and heat is produced]; but we do not know in which of the two forms, if either, the energy which comes out as heat existed in the chemical process. For such a case the conservation of energy is only a probable statement (though of great probability) to the effect that in all cases where a physical quality is convertible with energy, that quality is itself either energy of motion or energy of position.

General Results.—Force is a quality of position, definite in magnitude and direction at any point; not constant.

Energy is the name of two different quantities.

1. Energy of motion, half the rate at which a body carries momentum.

2. Energy of position, defined by the statement of the law that the work done in getting from one position to another is the same by whatever path the change of position is made.

[The definition of these conceptions helps to clear up sundry questions of mixed physics and metaphysics.]

1. Is a physical force, such as the attraction of the earth, analogous to our "exertion of force" in muscular work? No, for the sensation of muscular effort is very complicated. It involves nerve and muscle, which we know not to be present in the simpler cases, *e.g.*, the motion of a stone let fall. To talk of *pushing* or *pulling* in such a case is a personification of external nature.

2. Are we directly conscious of force? It is often said in physical and metaphysical works that we are. It may be true, but it is at least premature. We do not *know* that the chemical changes in nerve-matter corresponding to consciousness are energy [only that they are *convertible with* dynamical energy]; much less do we know that they are force. If they are energy, it is energy of motion, not energy of position, since consciousness does not depend on the position of the nerve-matter [so my notes: *sed quære*].

3. Is mind a force? It is held by some that the will acts as the match to gunpowder, by setting loose a store of energy, the matter of the brain being in unstable equilibrium. But you cannot have in nature an absolutely unstable equilibrium [*i.e.*, an equilibrium capable of being upset by an infinitesimal force], because the universe is not at rest [and every motion in the universe produces a finite change, however small, in the resultant force at every point of space]. Therefore if mind is force, operating in the way suggested, it must be able to create a determinate quantity of energy. This is a supposition which, if true, would destroy its own evidence; for it would destroy the uniformity of nature, on which all possibility of inference ultimately rests.

[The discourse concluded by pointing out that even from a purely scientific point of view, metaphysical speculation is to be encouraged as a spur to science.]

ECHIS CARINATA

THOSE who are interested in the poisonous snakes of India may have an opportunity of seeing one of the most interesting and destructive of these reptiles, now in the Zoological Society's Gardens in Regent's Park.

The snake I refer to is a fine specimen of the *Echis carinata*, which has recently arrived from India, and is the first of its kind, I am told, that has been received alive in this collection. I think it is probable, however, that a snake so common in some parts of India must have been brought alive to England before; but at any rate it is rare, and sufficiently interesting to claim attention, especially as it is healthy, vigorous, and active, and readily shows its peculiar habits, in the attitude it assumes and the rustling sound it gives rise to by the friction of the carinated scales of one fold of its body against those of the other when alarmed, and in the aggressive position which it takes up when prepared to strike, which it does most viciously by launching out its head and the anterior part of its body from the centre of the convoluted folds into which it has arranged itself. There are, I believe, only two true vipers in India (though there are several Crotalidæ), the *Daboia russellii*, or chain viper, or ticpolonga, and the *Echis carinata*. The daboia is well known here, and there are, or have been lately, fine specimens in the Society's collection; but the echis is not so well known, though common enough in India.

It is much smaller than the Daboia, and is very active and dangerous. It is known in Sind as the "kuppur"; in other parts of the country as "phoorsa"; about Delhi it is "afäe," or "afai" (a word of Arabic origin). Russell calls it "horatta pam." It seldom attains more than the length of 20 to 22 or 23 inches; probably 15 or 16 inches is more common, and is from 2 to 2½ or 3 inches in circumference at the thickest part of the body.

It is very fierce and aggressive, always ready to attack. It throws itself into a double coil, the folds of which are in perpetual motion; the whole body does not necessarily change its place, and as they rub against each other they make a loud rustling sound, which may be mistaken for hissing. This is produced by the three or four outer rows of carinated scales, which are prominent and point downwards at a different angle to the rest; their friction against each other causes the loud rustling sound which gives notice of the presence of the echis, as does the rattle of the crotalus.

I have never heard this viper hiss; though the daboia does so loudly. It is of a brownish-grey colour, with white and dark spots, and a waving whitish band on either side of the body. On the head there is a peculiar mark something like a cross. Its fangs are very long and mobile, and its poison very active, destroying a fowl in two or three minutes. In Sind, and some other parts of India where it is very common, it causes considerable loss of human life, though I believe it is not so destructive on the whole as either the cobra or *Bungarus cæruleus* (Krait), which are more generally distributed over the peninsula. I have not seen it in Bengal, but it is common in the North-West Provinces, Punjab, Sind, and Central Provinces, and Southern India in the Carnatic, and about Madras.

Its aggressive aspect when roused, the vicious eye, its peculiar method of folding itself, the rustling of its scales, and the rapidity with which it strikes, make it, when living, an object of considerable interest.

In the same collection there is a fine specimen of another very rare colubrine venous snake, the *Ophiophagus elaps*, which gives an opportunity not often available even in India, where the snake is found only in certain localities, of studying its peculiar habits and food, which consists of other snakes. It is as deadly as the cobra, to which it is nearly allied; but from its comparative rarity and the nature of its habitat it does not contribute so largely to the death-rate as that snake or even as the little echis.

J. FAYRER